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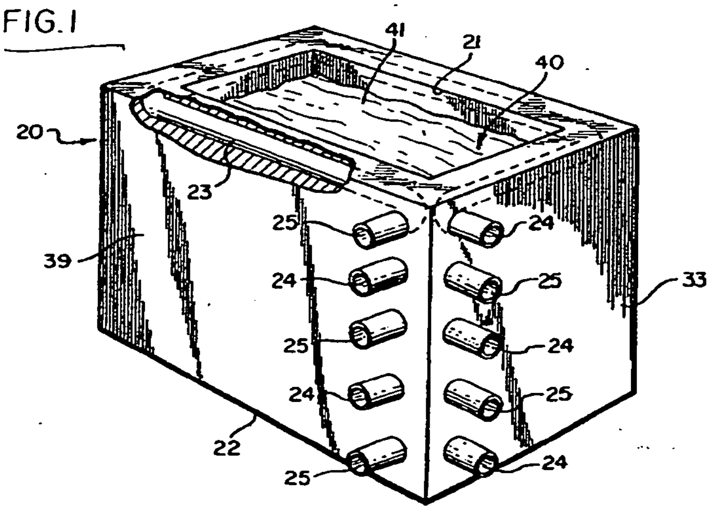
(54) Break-out detection in continuous casting.

(57) A method and apparatus for predicting the likelihood of a break-out during continuous casting of molten metal in a vertical mold. A continuous determination is made of (a) the location within the mold of the molten metal level and (b) the peak temperature location within the mold, both in relation to the top of the mold. The vertical distance between (a) and (b) is noted, and that distance is continuously monitored to detect any increase therein. A substantial increase indicates the likelihood of a breakout unless corrective action is taken.

FIG. 1



EP 0 389 139 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 30 2314

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	PATENT ABSTRACTS OF JAPAN vol. 8, no. 128 (M-302)(1565), 14 June 1984; & JP - A - 5930458 (SUMITOMO) 18.02.1984 ---	1,12,17	B 22 D 11/16 B 22 D 11/20
Y	PATENT ABSTRACTS OF JAPAN vol. 10, no. 196 (M-497)(2252), 10 July 1986; & JP - A- 6138763 (NIPPON KOKAN) 24.02.1986 ---	1,12,17	
A	GB-A- 777 354 (BRITISH IRON & STEEL) * claims 1,2 * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B 22 D 11/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	28-02-1991	GOLDSCHMIDT G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

and continuously monitoring said vertical distance to detect any increase therein.

2. A method as recited in claim 1 wherein said step of determining the location of said peak temperature comprises:
measuring the mold wall temperature at each of a multiplicity of vertically spaced locations between said upper and lower mold ends.

3. A method as recited in claim 1 and comprising:
providing said mold with a multiplicity of vertically spaced, horizontally disposed, cooling channels at locations between said upper and lower mold ends; and circulating cooling liquid through each of said channels.

4. A method as recited in claim 3 wherein:
said cooling liquid is circulated at the same flow rate through each of said channels;
and said location of said peak temperature is determined by determining the temperature differentials for the cooling liquid entering and exiting each channel.

5. A method as recited in claim 3 wherein:
said location of said peak temperature is determined by determining the mold heat transfer rate (MHTR) at each of said channels.

6. A method as recited in claim 1 and comprising:
actuating an alarm in response to the detection of a substantial increase in said distance.

7. A method as recited in claim 1 and comprising:
actuating an alarm when said distance is greater than about 3 inches (7.6 cm).

8. A method as recited in claim 1 and comprising:
actuating an alarm when said distance is greater than about 15% of the vertical dimension of said mold.

9. In combination with the method recited in any one of the preceding claims, the step comprising:
initiating corrective action to prevent a break-out, in response to the detection of a substantial increase in said distance.

10. In the combination of claim 9 wherein said corrective action comprises at least one of the following steps:

(a) decreasing the rate at which said shell is withdrawn from said mold; and

(b) raising the molten metal level in said mold.

11. In the combination of claim 10 wherein said corrective action is step (b).

12. In a continuous casting process for forming a cast metal shell, wherein molten metal descends through a vertically disposed, liquid-cooled mold having an upper end, an open lower end, and a predetermined vertical dimension, a method for predicting the likelihood of a molten metal break-out from said shell, at said lower end of the mold, said method comprising the steps of:
providing said mold with a multiplicity of vertically spaced, horizontally disposed, cooling channels at locations between said upper and lower mold ends;
circulating cooling liquid through said channels;
continuously measuring the flow rate of the liquid entering each channel, throughout the casting operation;
continuously measuring the temperature of the liquid entering each channel, throughout the casting operation;
continuously measuring the temperature of the liquid exiting each channel, separately for each of said channels, throughout the casting operation;
continuously calculating, from the measurements obtained in said three above-recited measuring steps, the mold heat transfer rate (MHTR) at each of said channels;
continuously determining the molten metal level location in said mold, throughout the casting operation;
plotting, on a graph in which one coordinate is said MHTR and the other coordinate is the vertical distance from the top of the mold, a curve showing the MHTR along said vertical dimension between said upper and lower ends of the mold;
depicting, on said graph, the location of said molten metal level in relation to the top of the mold;
periodically changing said curve to reflect change in said MHTRs;
periodically changing the depiction on said graph of said molten metal level location, to reflect change in the location of said molten metal level in relation to the top of the mold;
noting from said curve the location of the peak MHTR in relation to the top of the mold;
noting, from the information represented on said graph, the vertical distance between (a) said peak MHTR location and (b) said molten metal level location;
and continuously monitoring said vertical distance to detect any increase in said distance.

13. In a continuous casting process for forming a cast metal shell, wherein molten metal descends through a vertically disposed, liquid-cooled mold having an upper end, an open lower end, and a predetermined vertical dimension, a method for predicting the likelihood of a molten metal break-out from said shell, at said lower end of the mold, said method comprising the steps of:
providing said mold with a multiplicity of vertically spaced, horizontally disposed, cooling channels at locations between said upper and lower mold ends;
circulating cooling liquid at the same flow rate through each of said channels;

continuously measuring the temperature of the liquid entering each channel, throughout the casting operation;
continuously measuring the temperature of the liquid exiting each channel, separately for each of said channels, throughout the casting operation;
continuously calculating, for each of said channels, the temperature differential of the cooling liquid which circulated through that channel;
continuously determining the molten metal level location in said mold, throughout the casting operation;
plotting, on a graph in which one coordinate is said temperature differential and the other coordinate is the vertical distance from the top of the mold, a curve showing the temperature differential along said vertical dimension between said upper and lower ends of the mold;
depicting, on said graph, the location of said molten metal level in relation to the top of the mold;
periodically changing said curve to reflect change in said temperature differentials;
periodically changing the depiction on said graph of said molten metal level location to reflect change in the location of said molten metal level in relation to the top of the mold;
noting from said curve the location of the peak temperature differential, in relation to the top of the mold;
noting, from the information represented on said graph, the vertical distance between (a) said peak tempterature differential location and (b) said molten metal level location;
and continuously monitoring said vertical distance to detect any increase in said distance.

14. A method as recited in Claim 12 or Claim 13 wherein said periodic changing of said curve occurs at a time interval less than ten seconds.

15. A method as recited in claim 14 wherein said periodic changing of said depiction of the molten metal level location occurs at a time interval less than ten seconds.

16. A method as recited in claim 14 or claim 15 wherein said time interval is less than about five seconds.

17. In a continuous casting process for forming a cast metal shell, wherein molten metal descends through a vertically disposed, liquid-cooled mold having walls, an upper end, an open lower end, and a predetermined vertical dimension, a method for predicting the likelihood of a molten metal break-out from said shell, at said lower end of the mold, said method comprising the steps of:
continuously measuring the wall temperature of the mold at each of a multiplicity of vertically spaced locations between said upper and lower mold ends;
continuously determining the molten metal level location in said mold, throughout the casting operation;
plotting, on a graph in which one coordinate is said mold wall temperature and the other coordinate is the vertical distance from the top of the mold, a curve showing the mold wall temperature along said vertical dimension between said upper and lower ends of the mold;
depicting, on said graph, the location of said molten metal level in relation to the top of the mold;
periodically changing said curve to reflect change in said mold wall temperatures;
periodically changing the depiction on said graph of said molten metal level location to reflect change in the location of said molten metal level in relation to the top of the mold;
noting from said curve the location of the peak mold wall temperature, in relation to the top of the mold;
noting, from the information represented on said graph, the vertical distance between (a) said peak mold wall temperature location and (b) said molten metal level location;
and continuously monitoring said vertical distance to detect any increase in said distance.

18. In continuous casting equipment for forming a cast metal shell from molten metal wherein said equipment includes a vertically disposed mold having walls, an upper end and an open lower end, and said mold has a predetermined vertical dimension, apparatus for predicting the likelihood of a molten metal break-out from said shell, at said lower end of the mold, said apparatus comprising:
means for continuously determining the location of the molten metal level in said mold, in relation to the top of the mold;
means for continuously determining the location of the peak temperature within said mold, in relation to the top of the mold;
means for noting the vertical distance between (a) said peak temperature location and (b) said molten metal level location;
and means for continuously monitoring said vertical distance to detect any increase therein.

19. Apparatus as recited in claim 18 wherein said means for determining the location of said peak temperature comprises:
a multiplicity of temperature sensor means located in the mold wall at vertically spaced locations between said upper and lower mold ends.

20. Apparatus as recited in claim 18 and comprising:
a multiplicity of vertically spaced, horizontally disposed, cooling channels in said mold at locations between said upper and lower mold ends;
and means for circulating a cooling fluid through each of said channels.

21. Apparatus as recited in claim 20 and comprising:

means for circulating said cooling liquid at the same flow rate through each of said channels;
said means for determining said peak temperature location comprising means for determining the temperature differentials for the cooling liquid entering and exiting each channel.

22. Apparatus as recited in claim 20 wherein said means for determining said peak temperature location comprises:
means for determining the mold heat transfer rate (MHTR) for each of said channels.

23. Apparatus as recited in claim 18 and comprising:
means for actuating an alarm in response to the detection of a substantial increase in said distance.

24. Apparatus as recited in claim 18 and comprising:
means for actuating an alarm when said distance is greater than about 3 inches (7.6 cm).

25. Apparatus as recited in claim 18 and comprising:
means for actuating an alarm when said distance is greater than about 15% of the vertical dimension of said mold.

26. In continuous casting equipment for forming a cast metal shell from molten metal wherein said equipment includes a vertically disposed mold having an upper end and an open lower end, and said mold has a predetermined vertical dimension, apparatus for predicting the likelihood of a molten metal break-out from said shell, at said lower end of the mold, said apparatus comprising:
a multiplicity of vertically spaced, horizontally disposed, cooling channels in said mold at locations between said upper and lower mold ends;
means for circulating cooling liquid through said channels;
means for continuously measuring the flow rate of the liquid entering each channel;
means for continuously measuring the temperature of the liquid entering each channel;
means for continuously measuring, separately for each channel, the temperature of the liquid exiting each channel;
means for continuously determining the molten metal level location in said mold;
computer means;
means for feeding each of said temperatures and flow rate measurements into said computer means;
means for feeding the molten metal level determination into said computer means;
said computer means comprising each of the following elements (a)-(i):

(a) means for calculating, from the temperature and flow rate measurements fed into said computer means, the mold heat transfer rate (MHTR) at each of said channels;

(b) means for displaying a graph in which one coordinate is said MHTR and the other coordinate is the vertical distance from the top of the mold;

(c) means for plotting, on said graph, a curve showing the variation in MHTR along said vertical dimension between said upper and lower ends of the mold;

(d) means for depicting, on said graph, the location of said molten metal level in relation to the top of the mold;

(e) means for periodically changing said curve to reflect change in said MHTR's;

(f) means for periodically changing the depiction on said graph of said molten metal level location, to reflect change in the location of said molten metal level in relation to the top of the mold;

(g) means for noting the location on said curve of the peak MHTR, in relation to the top of the mold;

(h) means for noting, from the information represented on said curve, the vertical distance between said peak MHTR location and said molten metal level location;

(i) and means for continuously monitoring said vertical distance to detect any increase in said distance.

27. In continuous casting equipment for forming a cast metal shell from molten metal wherein said equipment includes a vertically disposed mold having an upper end and an open lower end, and said mold has a predetermined vertical dimension, apparatus for predicting the likelihood of a molten metal break-out from said shell, at said lower end of the mold, said apparatus comprising:
a multiplicity of vertically spaced, horizontally disposed, cooling channels in said mold at locations between said upper and lower mold ends;
means for circulating cooling liquid at the same flow rate through each of said channels;
means for continuously measuring the temperature of the liquid entering each channel;
means for continuously measuring, separately for each channel, the temperature of the liquid exiting each channel;
means for continuously determining the molten metal level location in said mold;
computer means;
means for feeding each of said temperature measurements into said computer means;
means for feeding the molten metal level determination into said computer means;
said computer means comprising each of the following elements (a)-(i):

(a) means for calculating, for each of said cooling channels, the temperature differential of the cooling liquid which circulated through that channel;

(b) means for displaying a graph in which one coordinate is said temperature differential and the other coordinate is the vertical distance from the top of the mold;

(c) means for plotting, on said graph, a curve showing the temperature differential along said vertical dimension between said upper and lower ends of the mold;

(d) means for depicting, on said graph, the location of said molten metal level in relation to the top of the mold;

(e) means for periodically changing said curve to reflect change in said temperature differentials;

(f) means for periodically changing the depiction on said graph of said molten metal level location, to reflect change in the location of said molten metal level in relation to the top of the mold;

(g) means for noting the location on said curve of the peak temperature differential, in relation to the top of the mold;

(h) means for noting, from the information represented on said curve, the vertical distance between said peak temperature differential location and said molten metal level location;

(i) and means for continuously monitoring said vertical distance to detect any increase in said distance.

28. In continuous casting equipment for forming a cast metal shell from molten metal wherein said equipment includes a vertically disposed mold having walls, an upper end and an open lower end, and said mold has a predetermined vertical dimension, apparatus for predicting the likelihood of a molten metal break-out from said shell, at said lower end of the mold, said apparatus comprising:
means for continuously measuring the wall temperature of the mold at each of a multiplicity of vertically spaced locations between said upper and lower mold ends;
means for continuously determining the molten metal level location in said mold;
computer means;
means for feeding each of said temperature measurements into said computer means;
means for feeding the molten metal level determination into said computer means;
said computer means comprising each of the following elements (a)-(h):

(a) means for displaying a graph in which one coordinate is said mold wall temperature and the other coordinate is the vertical distance from the top of the mold;

(b) means for plotting, on said graph, a curve showing said mold wall temperature along said vertical dimension between said upper and lower ends of the mold;

(c) means for depicting, on said graph, the location of said molten metal level in relation to the top of the mold;

(d) means for periodically changing said curve to reflect change in said mold wall temperatures;

(e) means for periodically changing the depiction on said graph of said molten metal level location, to reflect change in the location of said molten metal level in relation to the top of the mold;

(f) means for noting the location on said curve of the peak mold wall temperature, in relation to the top of the mold;

(g) means for noting, from the information represented on said curve, the vertical distance between said peak mold wall temperature location and said molten metal level location;

(h) and means for continuously monitoring said vertical distance to detect any increase in said distance.

FIG. 1

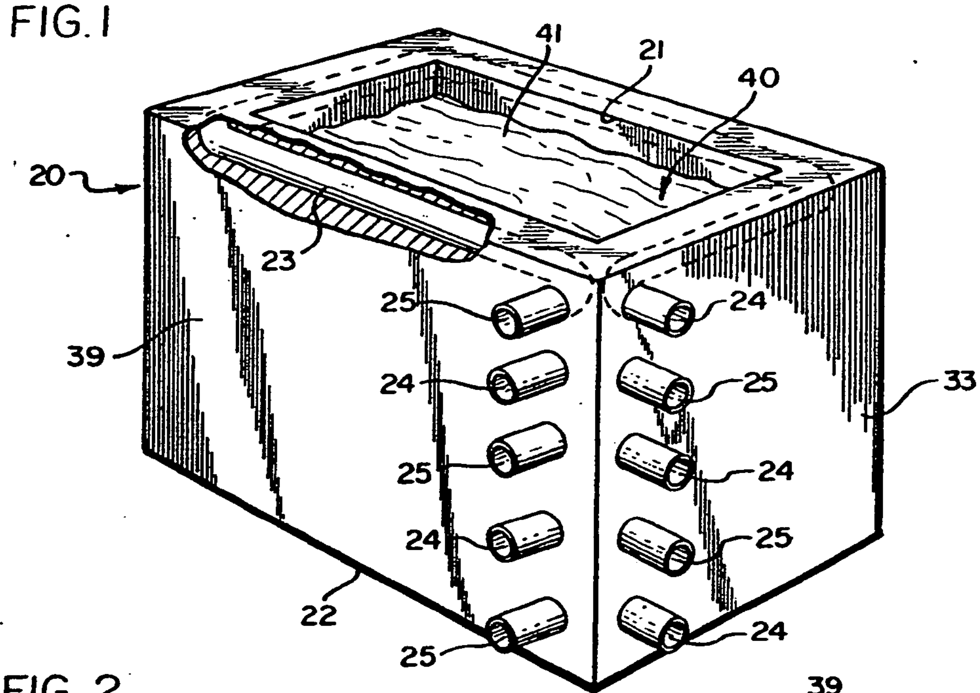


FIG. 2

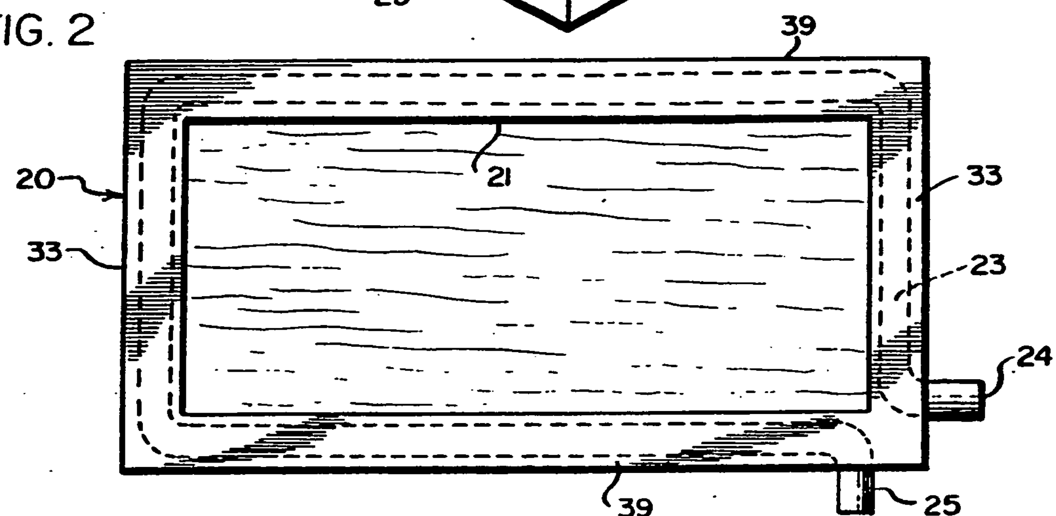


FIG. 3

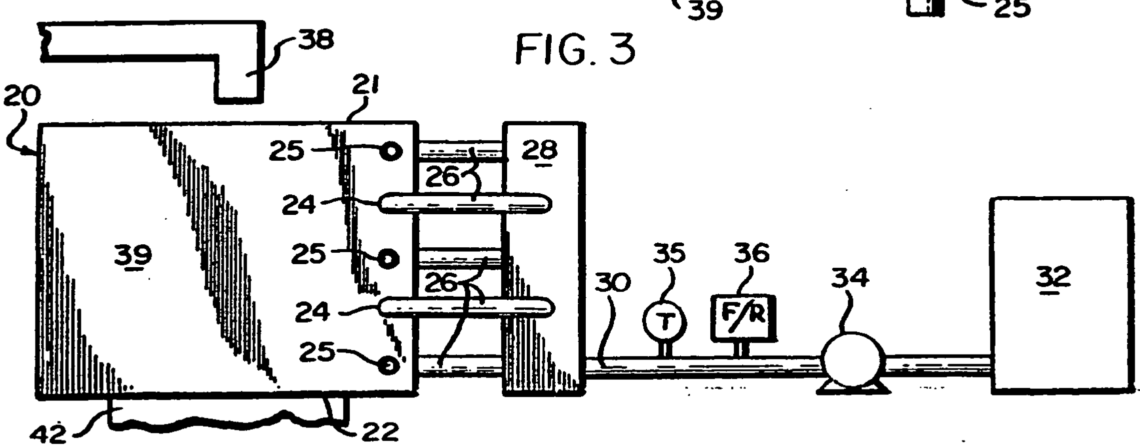


FIG. 4

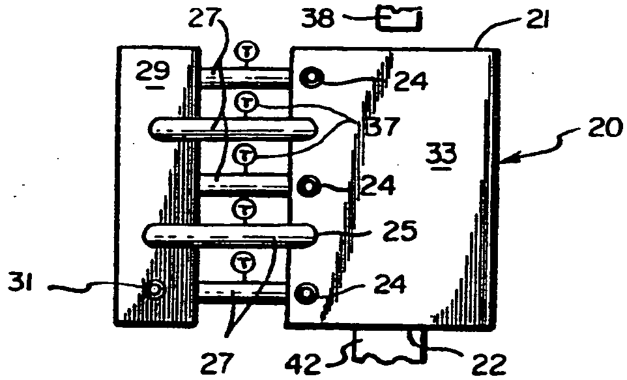


FIG. 5

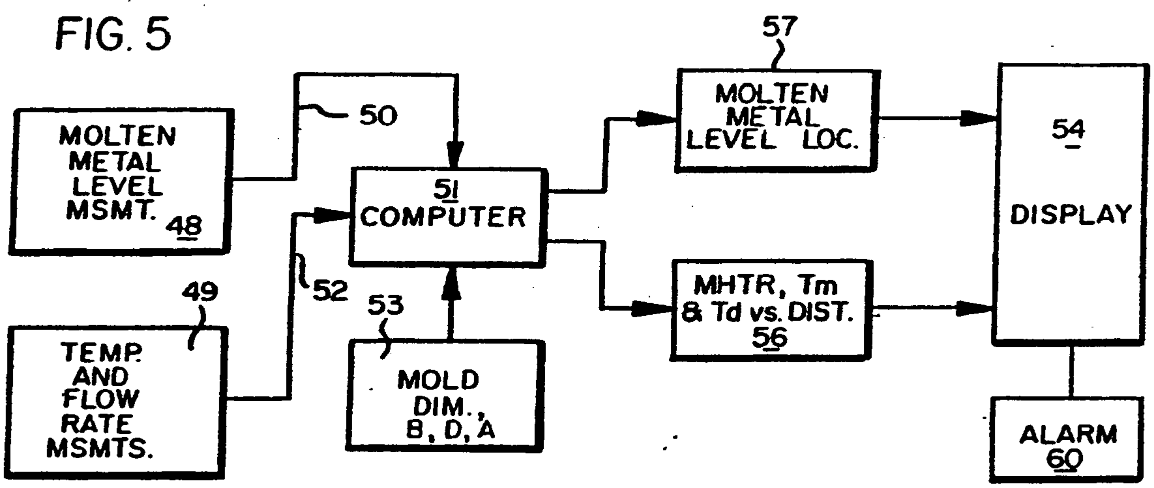


FIG. 6

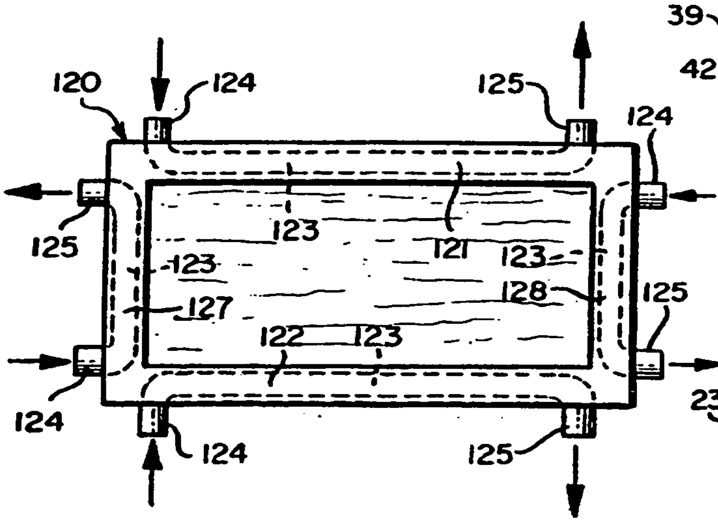


FIG. 7

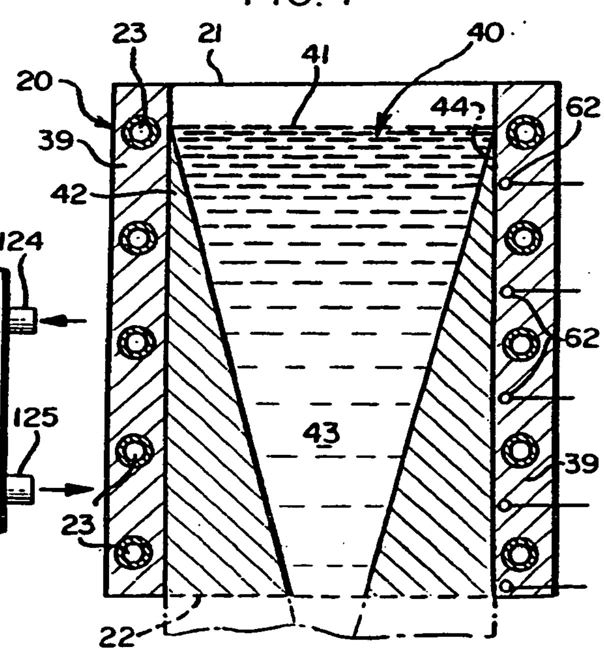


FIG. 8

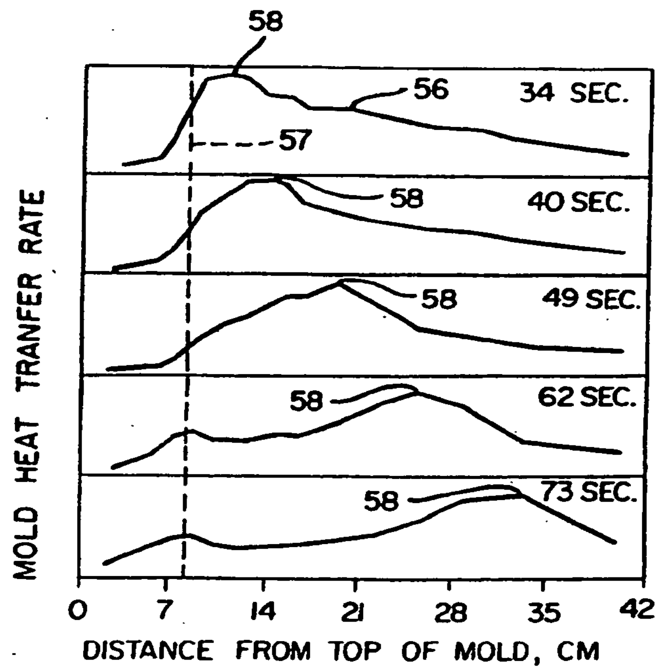

58
56
34 SEC.
57
58
40 SEC.
58
49 SEC.
58
62 SEC.
58
73 SEC.
MOLD HEAT TRANFER RATE
0
7
14
21
28
35
42
DISTANCE FROM TOP OF MOLD, CM

FIG. 9

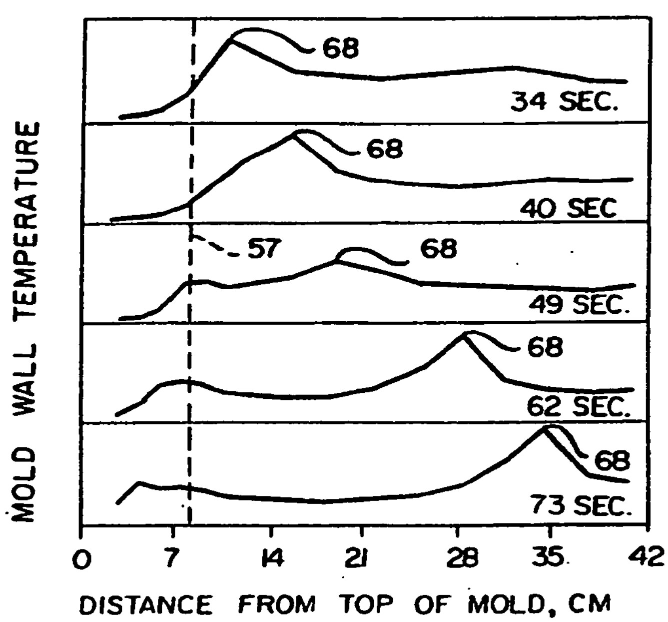
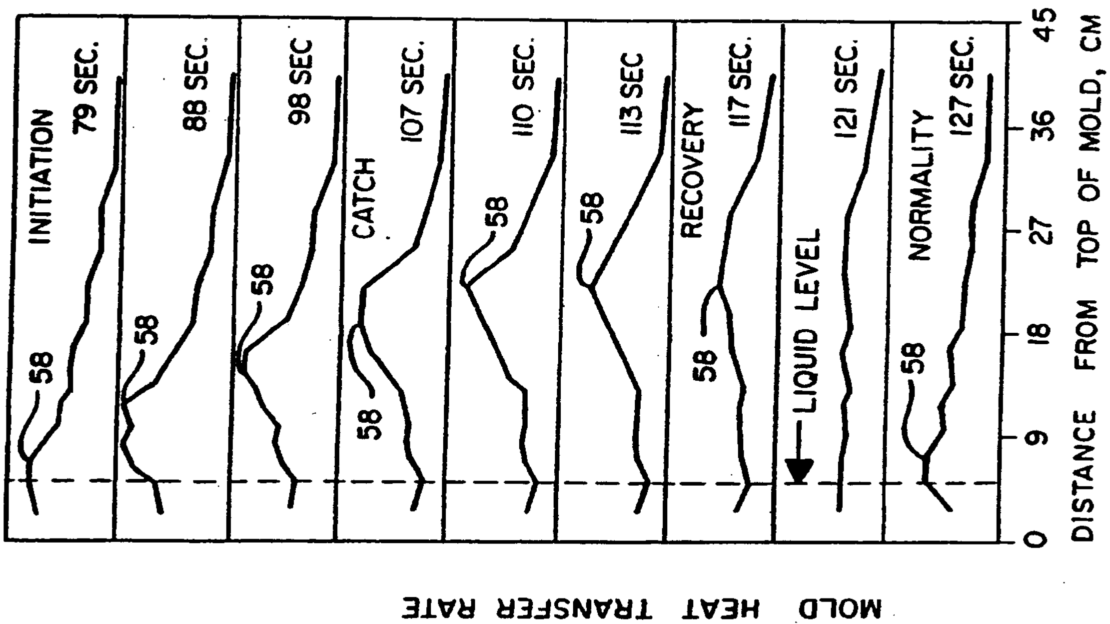

68
34 SEC.
68
40 SEC
57
68
49 SEC.
68
62 SEC.
68
73 SEC.
MOLD WALL TEMPERATURE
0
7
14
21
28
35
42
DISTANCE FROM TOP OF MOLD, CM

FIG.11


INITIATION
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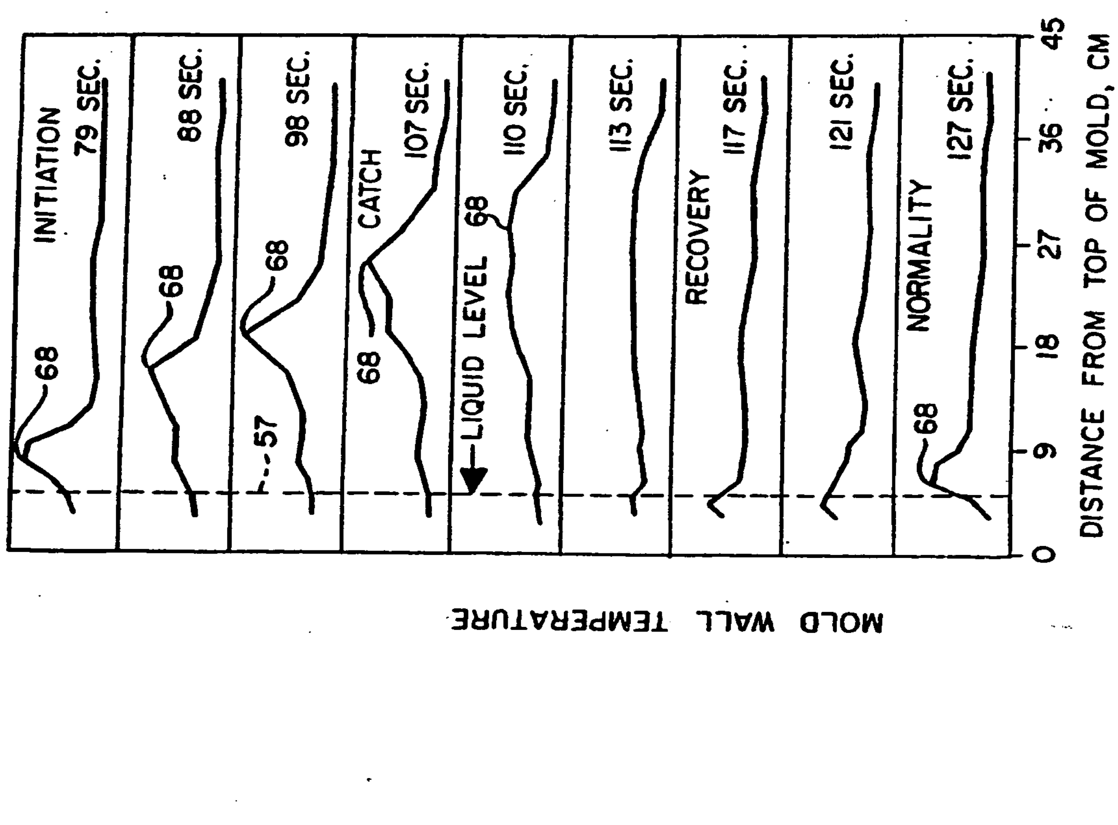
88 SEC.
98 SEC
CATCH
107 SEC.
110 SEC.
113 SEC
RECOVERY
117 SEC.
121 SEC.
NORMALITY
127 SEC.
58
LIQUID LEVEL
0
9
18
27
36
45
DISTANCE FROM TOP OF MOLD, CM
MOLD HEAT TRANSFER RATE

FIG.10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NORMALITY
127 SEC.
68
57
LIQUID LEVEL
0
9
18
27
36
45
DISTANCE FROM TOP OF MOLD, CM
MOLD WALL TEMPERATURE